WATER RESOURCES REPORT 18

GROUNDWATER RESOURCES OF ATCHISON COUNTY, MISSOURI

by G. E. Heim. Jr., J. A. Martin, and W. B. Howe

1960

ISSOURI GEOLOGICAL SURVEY AND WATER RESOURCES

Preliminary Report

on the

GROUNDWATER RESOURCES OF ATCHISON COUNTY, MISSOURI

by

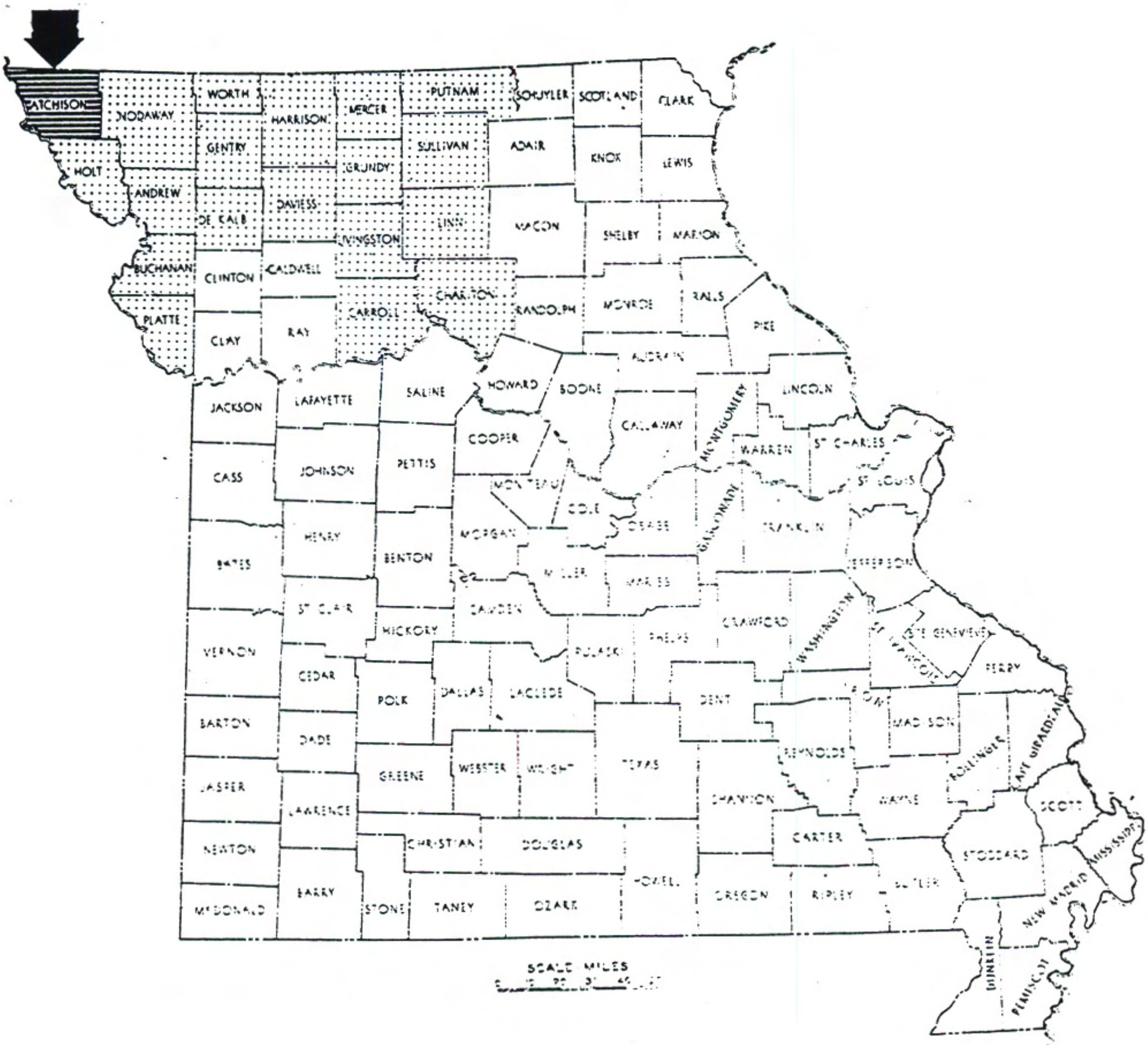
G. E. Heim, Jr., J. A. Martin and W. B. Howe

February 1960

STATE OF MISSOURI
Department of Business and Administration
Division of
GEOLOGICAL SURVEY AND WATER RESOURCES
THOMAS R. BEVERIDGE, State Geologist
Rolla, Missouri

PRELIMINARY REPORT ON THE GROUNDWATER RESOURCES

ATCHISON COUNTY, MISSOURI



COUNTY COVERED BY THIS REPORT

COUNTIES IN WHICH TEST DRILLING HAS BEEN COMPLETED

FIGURE 1

GROUNDWATER RESOURCES OF ATCHSION COUNTY, MISSOURI

INTRODUCTION

This report has been prepared to aid in the location of groundwater supplies in Atchison County. Atchison County is one of many counties in western and northern Missouri in which there is either continual or periodic water shortage and especial difficulty in obtaining adequate amounts of usable ground water. This study is concerned with the location of areas within the county where ground water may be obtained for farm, irrigation, and municipal supplies. Emphasis is placed on ground water from the unconsolidated material above bedrock. Generally, this water is of better quality than either surface or bedrock water. Systematic test-drilling is the most reliable method of determining the areas in which this type of water occurs.

History of Program.-- The study is the continuation of a State sponsored groundwater program begun in 1955. Atchison County is the nineteenth county to be studied during this program. Figure 1 shows those counties on which groundwater reports are available from the Missouri Division of Geological Survey and Water Resources, Post Office Box 250, Rolla, Missouri.

The appended bibliography lists the previous work in the area of this report and in adjacent areas. Schweitzer (1892) gives a full discussion and description of the mineral springs and waters in Missouri. Hinds and Greene (1915) and McQueen and Greene (1938) present excellent discussions of the bedrock geology in this and adjacent areas. Their reports contain well logs and discussions on the stratigraphy and structural geology of

northwestern Missouri. Greene and Trowbridge (1935) discuss the preglacial drainage pattern of northwestern Missouri, and their pattern of the major channels is essentially correct. The present program has revealed many tributary channels and modifications of the major pattern. Flint (1957, p. 170) shows the regional drainage patterns during or preceding Pleistocene time. Kay and Apfel (1928) and Frye and Leonard (1952) present discussions of the Pleistocene deposits in adjacent states which may also be applied to this area of Missouri.

The report summarizes the results of the test-drilling program and discusses in detail the water possibilities and the quality of the water from various sources in the county. The information which it presents was derived from: (1) the extensive file of well logs maintained by the Missouri Geological Survey, (2) the study of 36 test holes, and (3) the published and unpublished material related to or concerning water supply in Atchison County.

The availability of data from the numerous drill-holes put down in Atchison County in the course of oil and gas exploration during past years has resulted in a very significant saving of time and money in the present investigation. In all, only 36 test holes were required to complete coverage comparable to that attained for adjacent counties. The necessary test-drilling was completed during the summer of 1959. Geologists made a detailed log of each hole as it was being drilled. Heim and Martin devoted full time to the test-drilling and associated work during that period and assembled the material for the present report. Richard Gentile of the Survey staff assisted in some of the logging work. The drilling

program and preparation of this report were carried out under the supervision of W. B. Howe.

Location and Size.-- Atchison County (Figure 1) is located in the northwestern part of Missouri. It includes 549 square miles and is the sixty-seventh largest county in the state. The population in 1930 was 13,421; in 1940, 12,897; and in 1950, 11,127. This represents a decrease in population of about 4 percent during the 1930-1940 period and a decrease of about 14 percent during the 1940-1950 period. In population, Atchison County ranked seventy-seventh out of the 114 counties in the state in 1950.

Acknowledgments.-- Mr. W. B. Russell of Layne-Western Company, Kansas City, Missouri, provided information on several wells that company has drilled in Atchison County.

Mr. Rex Lane of the Lane Drilling Company, Blanchard, Iowa, was kind enough to supply copies of logs from numerous wells which that company has drilled in the county.

Mr. F. C. Greene, formerly with the Missouri Geological Survey and now retired, discussed the groundwater problems of the county with the authors on numerous occasions. This assistance is gratefully acknowledged.

The writers also acknowledge the cooperation of Mr. Lloyd Brown, owner of the firm contracting the test-drilling work, and his employees, Mr. J. R. Lamme, driller, and Mr. Frank Benedict, assistant.

The writers also wish to thank the numerous State, County, and City officials for their cooperation. We wish to thank the Atchison County residents for their cooperation and interest.

GROUNDWATER RESOURCES

Ground water is defined as that part of rain and snowfall that soaks

into the soil and rock of the earth's crust and is stored there. The cracks and crevices and other open spaces in the layers of rock, and the open spaces or voids between grains of sand and gravel in unconsolidated deposits filling river valleys form a natural reservoir for the storage of water. The unconsolidated deposits, and other materials in the earth's crust such as sandstone and limestone, that are porous enough to hold quantities of water are called aquifers.

Ground water in Atchison County may be obtained from three sources: (1) alluvium, (2) glacial deposits, and (3) bedrock. Test holes were located in such a manner as to supply the maximum amount of information for the first two of these categories. Profiles of the major buried valleys were drilled in order to determine the thickness and extent of any water-bearing material. Survey geologists logged each hole as it was drilled, noting such information as the type of material (sand, silt, or clay), size of sand grains, loose drilling zones, and depth to bedrock. Samples were collected at five-foot intervals and were placed on file at the Survey's office in Rolla.

The test holes were drilled with a rotary drilling rig. No casing was used, and samples were collected from the circulating water.

Table 1 summarizes the information from the 36 test holes. This information gives the amount of sand in each test hole and gives in gallons per minute (gpm) the driller's estimate of water production which may be available in the vicinity of one or several test holes. Plate 2 shows the number and location of the test holes.

TABLE

SUMMARY OF TEST HOLE INFORMATION

Test Hole Number	Location T., R., Sec.	Elevation (feet above mean sea level	Depth to Bedrock (feet)	Total Amount of sand (feet)	Driller's Production Estimate (gpm)
1173	63-39-15	950	253	204	25
1174	63-39-1	982	238	175	5-10
1175	64-38-31	1028	211	110	20-30
1176	63-38-6	1088	269	79	2-3
1177	64-39-33	1046	293	88	10-20
1178	63-39-10	935	215	62	25-35
1179	63-39-5	999	263	89	15
1180	63-40-1	957	233	30	3-5
1181	63-38-16	1022	194	111	5-10
1182	64-38-7	996	174	109	5-10
1183	64-38-8	1070	220	164	25-30
1184	65-38-19	1124	284	88	5-10
1186	65-38-36	1094	325	226	150-200
1187	64-39-7	994	252	191	250-300
1188	64-39-5	1048	312	144	15-20
1189	64-39-4	982	256	98	3-5
1190	64-40-13	1051	314	103	5-10
1191	64-40-10	902	69	31	50-75
1192	64-40-9	940	71	14	3-5
1193	64-40-7	1080	230	65	3-5
1194	64-41-1	1073	246	44	2-5
1195	65-41-36	983	107	9	2-3
1196	65-40-29	1020	260	91	3-5
1197	65-40-19	1052	207	76	3-5
1198	65-40-11	1016	241	38	5-10
1199	65-40-9	1138	355	147	20-25
1200	66-40-32	1014	264	99	10-15
1201	66-41-25	1065	295	116	1-2
1202	66-41-16	944	155	40	2-3
1203	66-41-1	1040	303	260	150-200
1204	66-40-6	1056	Abandoned at 295 feet, heaving sand		
1205	66-40-6	1055	283	208	5-10
1206	66-40-8	1110	374	66	10
1207	66-40-28	1070	338	170	15-20
1208	66-40-22	1107	344	38	3-5
1209	66-40-11	1002	Abandoned at 55 feet, equip. trouble		

*The driller's estimate is based on the character of the sand and gravel, the way in which it drills (loose or tight) and knowledge of what wells in similar materials have produced.

Ground Water from Alluvial Deposits

Alluvium is the unconsolidated material associated with present day rivers and streams. It consists of clay, silt, sand, pebbles, and boulders. The major alluvial deposits in Atchison County are shown on Plate 1.

Missouri River Alluvium.-- The Missouri River floodplain in Atchison County encompasses approximately one-fourth of the total area of the county. No test holes were drilled in Missouri River alluvium in Atchison County. Data from other counties, which may be considered representative, indicates that production of 1200 gpm or more may be obtained. The Missouri Geological Survey has information on one producing well in Missouri River alluvium in Atchison County. Production from this well is 250 gpm; however, it is capable of producing [illegible] gpm. This alluvium is an excellent source for high yield wells. [illegible] thickness of Missouri River alluvium in Atchison County is [illegible] feet. See Table 3 for typical chemical analyses.

Tarkio River Alluvium.-- One test hole (No. 1191) was drilled in the alluvium of Tarkio River. Sixty-three feet of alluvium overlying 6 feet of glacial material was present. The driller estimated production to range from 50 to 75 gpm. The Missouri Geological Survey has information on one producing well in Tarkio River alluvium in Atchison County. This well produces 70 gpm. See Table 3 for an average chemical analysis.

Others.-- Alluvial deposits along other smaller rivers and streams in the county may produce small quantities of water, but the thickness and extent of the water-bearing material are quite variable.

Ground Water from Glacial Deposits

Most of Atchison County is covered by clay, silt, sand, gravel, and

boulders which were deposited during glacial time. When the glaciers entered Atchison County, they deposited this material and covered the then existing topography. Old drainage patterns were buried, and present day drainage developed on this unconsolidated material. In most instances, the buried drainage patterns do not correspond to the present drainage. The buried channel fillings of sand and gravel are much the same as the alluvial deposits of the present river channels. By means of systematic test drilling, it is possible to locate and define the pre-existing drainage and to predict areas of potential water production.

Glacial deposits are very complex. Production from shallow sands (depths less than 50 feet) is variable and in dry seasons often ceases. The deeper water-bearing material is more dependable for continued production and constant quantity. Plate 1 shows the thickness of the unconsolidated material in Atchison County.

A common misconception is that no water occurs below "blue clay." Of the 36 test holes which encountered glacial material, 33 encountered water-bearing material below the "blue clay."

The complex system of buried valleys in Atchison County is shown on Plate 2. The major valley enters Atchison County from Iowa in the vicinity of County Road H, trends southward approximately 6 miles, then turns to the southeast, passing under Tarkio. The channel bends to the south again and follows County Road N into Holt County. This buried valley contains many test holes which penetrated several feet of excellent water-bearing material

The broad, relatively flat area trending approximately north-south

through central Atchison County is controlled primarily by the bedrock, which in this area is a thick shale sequence. Well production within this area is variable. Several test holes penetrated thick water-bearing sands and gravel, while others encountered only scattered sand lenses. Test holes should definitely be drilled in this area before well sites are chosen.

The tributary channel in the Rockport area appears to be favorable for only small to moderate yields. Again, it is recommended that test holes be drilled to determine the presence and thickness of any water-bearing materials before a well site is chosen.

See Table 3 for typical chemical analyses of water from glacial deposits.

Ground Water from Bedrock

Limestone, shale, and sandstone are present at or near the surface along the Missouri River bluffs, in the vicinity of Rockport, and along the Tarkio River south of Fairfax. In this area, adequate amounts of usable water from wells is extremely difficult to obtain. No test holes were drilled into bedrock formations. Information on file at the Missouri Geological Survey indicates that water from bedrock (limestone, shale or sandstone) is generally too highly mineralized to be suitable for most uses. The principal constituents which make these waters unfit are the high sodium chloride (salt) and sulfate content. Chemical analyses of water from bedrock wells are listed in Table 3. Water from Devonian formations from very deep oil and gas test holes in Atchison County is reported to be much less highly mineralized than from the Pennsyl-

vanian formations. Confirmatory data in the form of detailed analyses are not yet available.

The Missouri Geological Survey has records of several wells that were drilled into bedrock in Atchison County. The majority of these were drilled for oil and gas exploration. The Survey files do not contain any records of wells which were drilled into bedrock for water. The possibilities of obtaining adequate quantities of usable water from the bedrock are very limited. Table 3 lists one representative analysis of bedrock water obtained from a hole drilled for an oil test. For additional analyses, see the Holt and Nodaway County reports.

WATER QUALITY

Water quality is commonly considered from two aspects, bacteriological and chemical. The importance and various limits of these aspects depend upon the use to which the water is to be put. The following discussion deals primarily with water to be used for domestic purposes.

Bacteriological -- The amount and type of bacteria in water is most important in determining its purity for drinking. Surface water supplies and groundwater supplies that may possibly be contaminated require periodic checking along with constant treatment with purifying agents to insure their safety. Bacteriological analysis reveals the presence of bacteria that may cause typhoid, dysentery, and other such diseases. Any surface supply should be considered contaminated and treated as such. By order of the Division of Health, Jefferson City, Missouri most groundwater supplies for public use in northwestern Missouri are treated as though contaminated.

In a properly constructed drilled well, there is not much danger of contamination. Proper construction includes adequate provisions for the exclusion of surface water and sterilization of the well upon its completion by the driller. Arrangements for a bacteriological analysis can be made through the district offices of the Division of Health and, in some cases, through the water department of the nearest town having a public water supply.

Chemical.-- The physical and chemical properties of water are very important in determining the type of treatment necessary to make the water usable. Table 2 lists some of the chemical characteristics of acceptable water. Chemical analyses are made by the Division of Health and by the Missouri Division of Geological Survey and Water Resources, Post Office Box 250, Rolla, Missouri.

TABLE 2

CHEMICAL CHARACTERISTICS OF WATER FOR DOMESTIC USE

Constituents	Maximum Allowable Amounts in Parts Per Million	Effect of Excess
Chloride	250.0	Salty taste
Fluoride	1.5	Mottling of teeth
Nitrate	45.0	Danger to infants
Iron	0.3	Staining
Sulfate	250.0	Permanent hardness

Other information given in a chemical analysis includes remarks about turbidity, odor, hardness, etc. This information can be used to determine the suitability of the water for household use, irrigation, or livestock; whether incrustation or corrosion of metals might occur; and also to indicate the type of treatment, such as softening or iron removal,

that might be beneficial.

In general, the water from alluvial and glacial deposits is hard and contains an excess of iron, and in many cases may require treatment. Bedrock water is more variable, but it is generally too high in chloride and sulfate to be usable.

CITY WATER SUPPLIES

The production given for cities having a municipal supply is based on the capacity of the existing water treatment plants and does not indicate the maximum potential yield of the aquifer.

Fairfax.-- Municipal water supply. City has one well in Tarkio River alluvium. The well is 49 feet deep and produces 70 gpm. The water is chlorinated, filtrated, aerated, and softened.

Phelps City.-- No municipal supply. Most likely area for future development, Missouri River alluvium.

Rockport.-- Municipal water supply. City has one well located in Missouri River alluvium. The well is 100 feet deep and can pump 500 gpm. Water treatment consists of filtration, chlorination, aeration, and addition of lime.

Tarkio.-- Municipal water supply. City has three wells with one in operation. The wells are located in the buried valley underlying Tarkio. The two abandoned wells are 205 and 207 feet deep. The producing well is 211 feet deep and yields 256 gpm. Water treatment consists of chlorination, filtration, aeration, and softening.

Watson.-- No municipal supply. Most likely area for future development, Missouri River alluvium.

Westboro.-- No municipal supply. Most likely area for future development, glacial material in buried valley.

EXPLANATION OF PLATES

The information shown on the Thickness Map (Plate I) and the Bedrock Contour Map (Plate 2) is accurate only to the degree of presently available data. As more information becomes available, these maps will be modified. The Thickness Map, based on the Bedrock Contour Map, is very generalized.

Plate 1 - Thickness of Unconsolidated Materials Map.-- This map, by means of patterns, shows the thickness of the unconsolidated material overlying the bedrock. In general, it can be said that the thicker the unconsolidated material, the greater the possibility of encountering water-bearing material. This map may be used to estimate the amount of potential water-bearing material available and the approximate depth of a well at a given point. The legend on the map shows the various thickness intervals used and the average estimated water possibilities from the various thicknesses. The figures used for the water possibilities are only an estimate and yields above or below those figures may be expected.

Figure 2 illustrates the manner in which the Thickness Map may be used. Point A lies in an area where the maximum thickness of unconsolidated material is approximately 200 feet and water possibilities are judged to be good. An estimate of the maximum cost of a well or test hole at Location A can be made by multiplying the cost per foot of a test hole or completed well by the maximum probable thickness in this case,

200 feet. Since water-bearing material may be encountered at less than 200 feet, this is an estimate of the maximum cost. Point B lies in an area where the maximum thickness of unconsolidated material is approximately 50 feet and the water possibilities are likely to be poor.

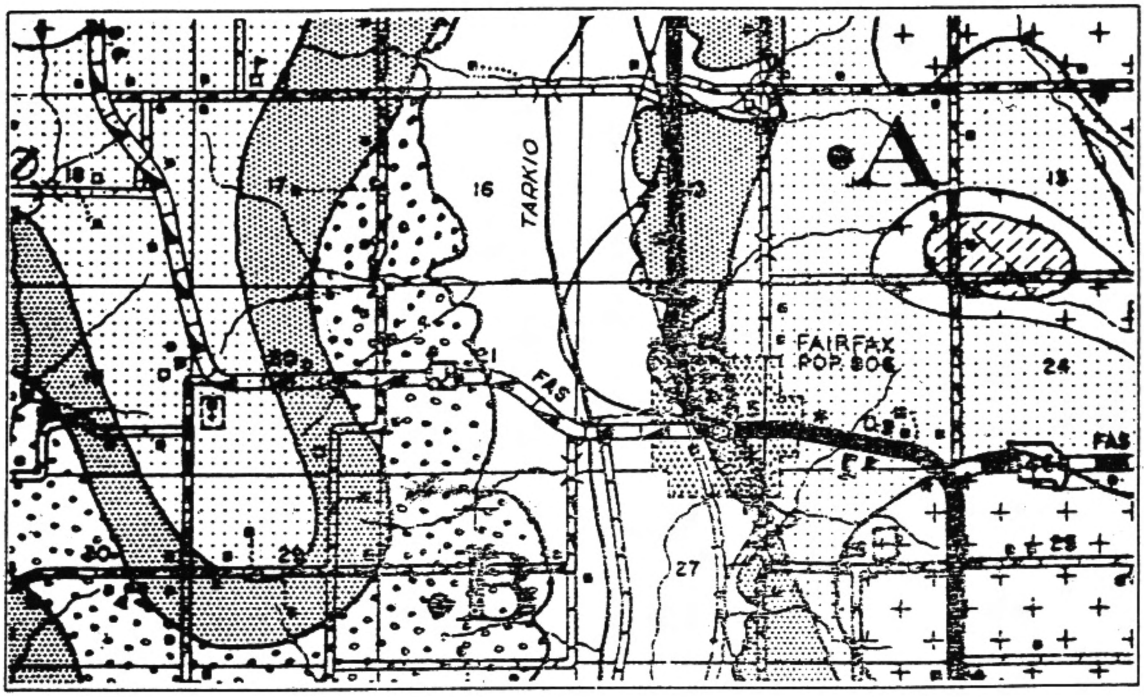


Figure 2. See Plate I for description of patterns.

<u>Plate 2 - Bedrock Contour Map</u>.-- This map, by means of contour lines, shows the configuration of the bedrock surface based on interpretation from drill hole data and bedrock exposures. This is the way the land surface would probably appear if all the unconsolidated material were removed. Contour lines are imaginary lines connecting points of equal elevation. The Bedrock Contour Map shows the valley system buried by glacial deposits. It was used in the preparation of the map showing the thickness of unconsolidated material.

SUMMARY

Properly constructed wells in the Missouri River alluvium can be expected to produce quantities of 1000 gpm or more. The Tarkio River alluvium will produce sufficient amounts of water for domestic purposes, small municipalities, and possibly irrigation. This water normally needs softening and treatment for removal of iron.

The occurrence of water in glacial deposits is more variable than water from alluvial deposits. Shallow wells, less than 50 feet in depth commonly experience seasonal variations in water level. In periods of prolonged drought, these wells very often go dry. The deeper wells are more likely to be consistent and will produce larger quantities of water than the shallow wells.

The buried river valleys are areas of potentially high-yield wells. However, because there are on record some wells of low-yield within these valleys, it is recommended that all the information available for such an area be obtained before any test is drilled.

Water from the glacial deposits may need treatment for hardness and removal of iron.

The possibility of obtaining adequate quantities of usable water from bedrock is very remote. In Atchison County, bedrock water is generally too highly mineralized to be fit for human consumption.

For further information write: Missouri Division of Geological Survey and Water Resources, Post Office Box 250, Rolla, Missouri. When writing for information, please send the exact location of your property. To aid in determining your location, see the page at the end of the report explaining the government land divisions.

BIBLIOGRAPHY

Bennison, E. W., 1947, Ground water, its development, uses, and conservation: Edward E. Johnson, Inc., St. Paul, 509 pp.

Flint, R. F., 1957, Glacial and Pleistocene geology: John Wiley & Sons, Inc., New York, 553 pp., 5 pls., 133 figs., 51 tables.

Frye, J. C., and Leonard, A. B., 1952, Pleistocene geology of Kansas: Kansas Geol. Survey, Bull. 99, 230 pp., 19 pls., 17 figs.

Greene, F. C., and Trowbridge, R. M., 1935, Preglacial drainage pattern of northwest Missouri: Missouri Bur. Geology and Mines, 58th Bienn. Rept. State Geologist, 1933-1934, app. 7, 7pp.

Heim, G. E., Jr., Martin, J. A., and Howe, W. B., 1959, Preliminary report on the groundwater resources of Nodaway County, Missouri: Missouri Geol. Survey and Water Resources, Ground Water Rept. No. 16, 24 pp., 2 pls., 1 fig., 3 tables.

Heim, G. E., Jr., Martin, J. A., and Howe, W. B., 1960, Preliminary report on the groundwater resources of Holt County, Missouri: Missouri Geol. Survey and Water Resources, Ground Water Rept. No. 17, 21 pp., 2 pl., 2 figs., 3 tables.

Hinds, Henry, and Greene, F. C., 1915, The stratigraphy of the Pennsylvanian series in Missouri: Missouri Bur. Geology and Mines, 2d ser. vol. 13, 407 pp.

Kay, G. F., and Apfel, E. T., 1928, Pre-Illinoian Pleistocene geology of Iowa: Iowa Geol. Survey Ann. Rept., 1928, vol. 34, pp. 1-304.

McQueen, H. S., and Greene, F. C., 1938, The geology of northwestern Missouri: Missouri Geol. Survey and Water Resources, 2d ser., vol. 25, 217 pp., 7 pls., 11 figs.

Schweitzer, Paul, 1892, A report on the mineral waters of Missouri: Missouri Geol. Survey and Water Resources, vol. 3, 256 pp.

TABLE 3

CHEMICAL ANALYSES OF WATER FROM VARIOUS SOURCES

Water from Missouri River Alluvium

Source: Rockport municipal supply, 3 analyses

Constituents	A	B Parts Per Million	C
Turbidity	0.4	50.0	60.0
pH	8.0	6.9	6.9
Alkalinity ($CaCO_3$)	329.0	513.0	524.0
Bicarbonate (HCO_3)	400.9	625.7	638.0
Silica (SiO_2)	28.0	38.0	20.0
Calcium (Ca)	44.0	116.0	101.6
Magnesium (Mg)	53.0	51.5	64.6
Sodium (Na) and Potassium(K)as Na	25.2	24.7	24.1
Iron (Fe)	0.3	7.0	5.0
Aluminum (Al)	0.1	0.1 -	0.1 -
Sulfate (SO_4)	18.1	17.9	18.9
Chloride (Cl)	15.5	13.8	14.3
Residue on Evaporation	466.0	648.0	703.0
Loss on Ignition	201.0	173.0	258.0
Total Hardness ($CaCo_3$)	328.0	502.0	520.0
Carbonate Hardness ($CaCO_3$)	328.0	502.0	520.0
Nitrate Nitrogen (N)	0.05	0.0	0.0

TABLE 3 (Cont.)

Water from Tarkio River Alluvium

Source: Fairfax municipal supply

Constituents	Minimum	Maximum	Average	Number of Analyses
	Parts Per Million			
Turbidity	0.2	160.0	45.0	5
Color	——	——	none	3
pH	6.7	7.6	6.9	5
Alkalinity ($CaCO_3$)	259.0	346.0	293.4	5
Bicarbonates (HCO_3)	315.0	422.0	357.8	5
Silica (SiO_2)	12.0	24.0	18.4	5
Calcium (Ca)	72.7	125.1	95.0	5
Magnesium (Mg)	26.1	42.7	34.4	5
Sodium (Na) and Potassium (K) as Na	23.6	53.7	36.5	5
Iron (Fe)	0.04	20.0	8.0	5
Sulfate (SO_4)	0.8	104.9	50.6	5
Chloride (Cl)	10.0	154.6	76.0	5
Residue on Evaporation	394.9	784.0	592.5	5
Loss on Ignition	120.0	430.0	246.6	5
Total Hardness ($CaCO_3$)	292.0	488.0	378.8	5
Carbonate Hardness ($CaCO_3$)	259.0	300.0	279.0	5
Noncarbonate Hardness ($CaCO_3$)	0.0	233.0	166.3	5
Nitrate Nitrogen (N)	0.0	1.3	0.8	3

TABLE 3 (Cont.)

Water from Glacial Deposits

Source: Tarkio municipal supply

Constituents	Minimum	Maximum	Average	Number of Analyses
	Parts Per Million			
Turbidity	0.1	10.0	3.1	7
Color	—	—	none	5
pH	8.2	9.4	—	2
Alkalinity ($CaCO_3$)	100.0	274.4	223.8	7
Carbonate (CO_3)	0.0	19.6	*	6
Bicarbonate (HCO_3)	82.3	334.3	267.2	7
Insoluble	25.2	29.2	27.2	5
Silica (SiO_2)	18.0	32.0	—	2
Iron and Aluminum Oxides	1.6	2.0	1.8	5
Calcium (Ca)	15.6	158.0	96.4	7
Magnesium (Mg)	26.7	51.1	37.0	7
Sodium Na) and Potassium (K) as Na	159.0	260.7	225.5	7
Iron (Fe)	0.7	1.8	0.88	7
Aluminum (Al)	0.1-	—	—	2
Sulfate (SO_4)	255.1	733.5	495.3	7
Chloride (Cl)	93.4	114.7	100.2	7
Fluoride (F)	0.1+	0.8	0.4	4
Residue on Evaporation	922.0	1752.0	1326.5	7
Loss on Ignition	111.0	777.0	289.4	7
Total Hardness ($CaCO_3$)	155.0	605.0	393.1	7
Carbonate Hardness ($CaCO_3$)	100.0	274.0	224.5	7
Noncarbonate Hardness ($CaCO_3$)	42.0	359.0	169.2	7
Nitrate Nitrogen (N)	0.3	2.7	1.49	6

*Carbonate - 5 analyses 0.0 ppm, 1 analysis 19.6 ppm.

TABLE 3 (Cont.)

Water from Glacial Deposits

Source: A - Owner: U. S. Department of Commerce
Location: 1¼ miles northeast of Tarkio, Mo.
Depth of Well: 176 feet.

B - Owner: Dr. C. L. Barnard
Location: SE¼ SE¼ SW¼ sec. 15, T. 66 N., R. 39 W.
Depth of Well: 295 feet.

C - Owner: Mr. O. C. Swackhamer
Location: SE¼ SW¼ NE¼ sec. 18, T. 64 N., R. 38 W.
Depth of Well: Not known.

Constituents	A	B Parts Per Million	C
Turbidity	Turbid	25.0	10.0
pH	ND	7.4	7.3
Alkalinity ($CaCO_3$)	115.6	212.5	256.0
Phenolpthalein	ND	0.0	0.0
Methyl Orange	ND	212.5	256.0
Carbonate (CO_3)	1.4	0.0	0.0
Bicarbonate (HCO_3)	141.0	259.2	312.3
Silica (SiO_2)	11.6	17.3	29.5
Oxides (Al_2O_3. Fe_2O_3, TiO_2, etc.)	ND	3.5	1.0
Calcium (Ca)	40.2	288.3	174.1
Magnesium (Mg)	8.6	100.3	60.5
Sodium (Na)and Potassium(K) as Na	25.2	333.6	230.9
Manganese (Mn)	0.0	0.0	1.0
Total Iron (Fe)	2.92	4.18	3.38
Dissolved Iron	0.45	0.57	0.08
Precipitated Iron	2.47	3.61	3.30
Sulfate (SO_4)	49.2	1445.7	791.0
Chloride (Cl)	10.0	61.1	49.5
Nitrate (NO_3)	4.25	0.0	5.1
Fluoride (F)	ND	0.7	0.6
Loss on Ignition	107.0	ND	ND
Total Suspended	3.30	0.0	40.0
Total Dissolved Solids	286.0	2580.0	1599.0
Total Hardness ($CaCO_3$)	135.8	1132.8	683.8
Carbonate Hardness ($CaCO_3$)	115.6	212.5	256.0
Noncarbonate Hardness ($CaCO_3$)	0.0	920.3	427.8
Temp. Hardness	91.1	ND	ND

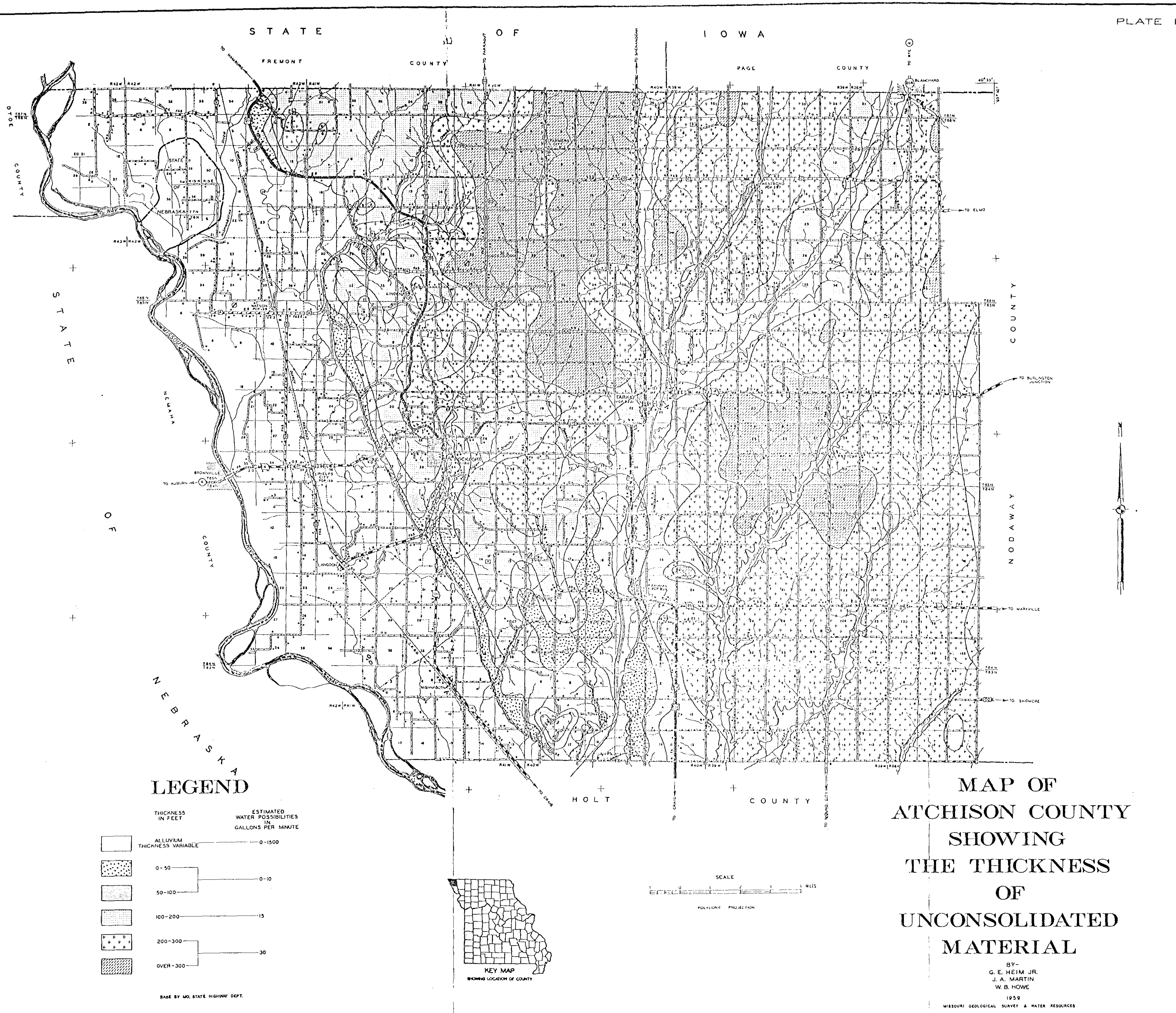
* ND - no determination

TABLE 3 (Cont.)

Water from Bedrock

Source - Owner:	Cities Service Oil Company, Jim Cook # 1
Location:	NW¼ Sec. 32, T. 65 N., R. 39 W.
Depth of Sample:	1450 feet. Pennsylvania sand (Lower Cherokee)

Constituents	Parts Per Million
Turbidity	Slight
Alkalinity ($CaCO_3$)	833.8
Carbonate (CO_3)	11.7
Bicarbonate (HCO_3)	1004.9
Insoluble	17.2
Oxides (Al_2O_3, Fe_2O_3)	6.8
Calcium (Ca)	8.4
Magnesium (Mg)	17.0
Sodium (Na) and Potassium (K) as Na	1789.5
Sulfate (SO_4)	16.7
Chloride (Cl)	2336.0
Loss on Ignition	48.0
Total Dissolved Solids	5128.0
Total Hardness ($CaCO_3$)	90.7



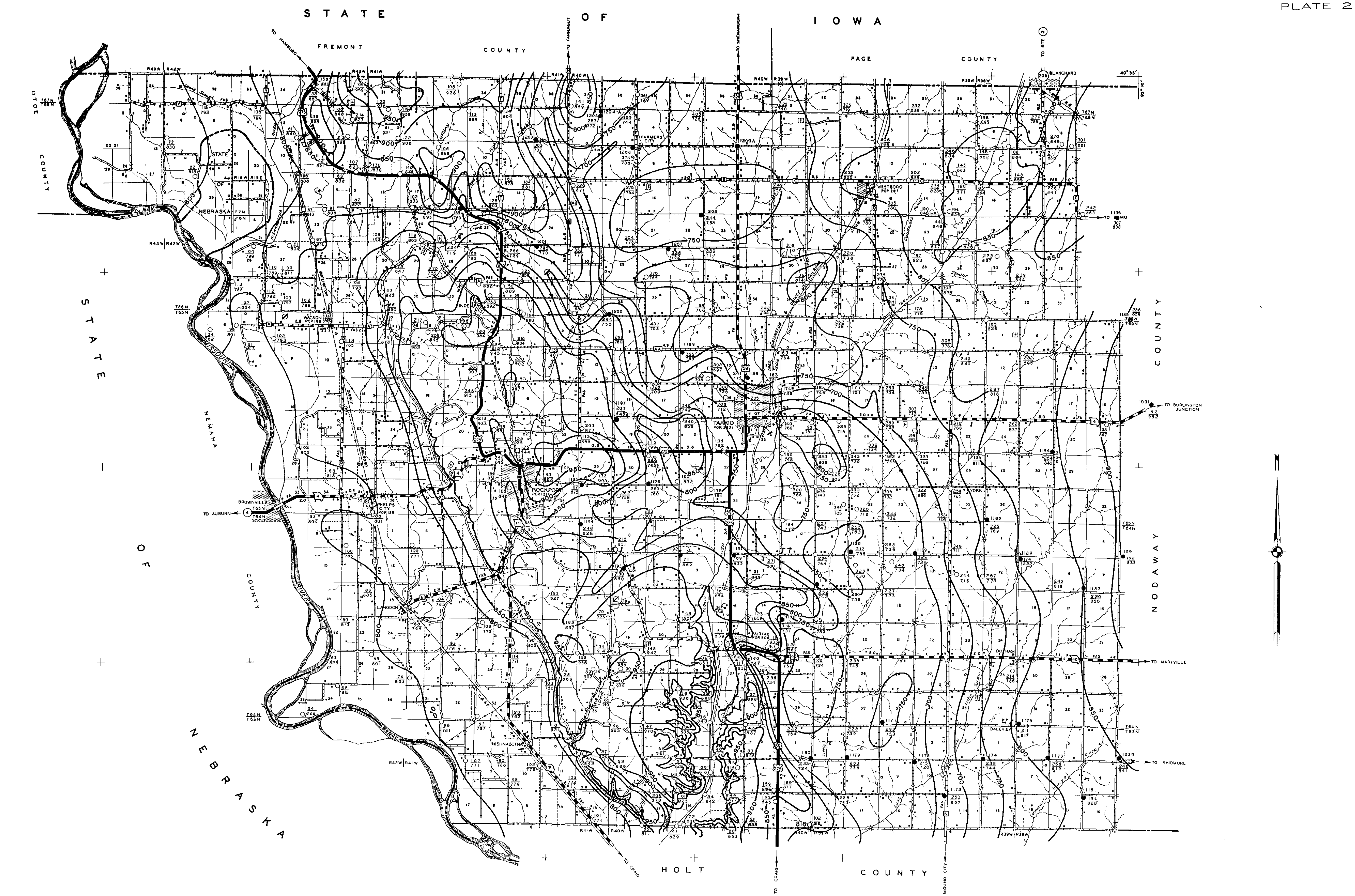
MAP OF ATCHISON COUNTY SHOWING THE THICKNESS OF UNCONSOLIDATED MATERIAL

BY-
G. E. HEIM JR.
J. A. MARTIN
W. B. HOWE

1959

MISSOURI GEOLOGICAL SURVEY & WATER RESOURCES

THOS. R. BEVERIDGE, STATE GEOLOGIST ROLLA, MO.



LEGEND

● M. G. S. TEST HOLE
SHOWING TEST HOLE NO.
LETTER (A) INDICATES AN ABANDONED HOLE

○ WATER WELL, OIL & GAS TEST, ETC.

244 — THICKNESS OF UNCONSOLIDATED MATERIAL
874 — BEDROCK ELEVATION

CONTOUR INTERVAL = 50'

BASE BY MO. STATE HIGHWAY DEPT.

SCALE

0 1 2 3 4 MILES

POLYCONIC PROJECTION

KEY MAP
SHOWING LOCATION OF COUNTY

MAP OF ATCHISON COUNTY SHOWING BEDROCK CONTOURS

BY
G. E. HEIM JR.
J. A. MARTIN
W. B. HOWE

1959

MISSOURI GEOLOGICAL SURVEY & WATER RESOURCES
ROLLA, MO.

THOS. R. BEVERIDGE
STATE GEOLOGIST